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OF  
**CIVIL ENGINEERS**



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# BOSTON SOCIETY OF CIVIL ENGINEERS

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BOSTON SOCIETY OF CIVIL ENGINEERS  
FOUNDED 1848

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PROCEEDINGS

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PAPERS IN THIS NUMBER.

"Some Features of New York City's Rapid Transit System."  
Robert Ridgway.

Memoir of Deceased Member.

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Contributors are hereby notified that proof will not be submitted to them for examination unless requested before the 10th of the month preceding the month of publication.

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SANITARY SECTION EXCURSION TO WORCESTER,  
June 5, 1918.

Members of the Boston Society of Civil Engineers are invited by the Officials of the City of Worcester, to inspect the Worcester Sewage Purification Works and Experimental Activated Sludge Plant, on June 5, 1918.

The party will leave South Station at 12 M. on Track 13. Special badges of identification will be distributed to the members as they enter the gate. At Union Station in Worcester a special trolley car will be provided by our hosts, which will take us to Greenwood Park, overlooking the Purification Works. Here we shall be entertained at lunch by the City Officials. After a short business meeting, Mr. Matthew Gault, Superintendent of the Sewer Department, will give us a brief account of Worces-



ter's Sewage Disposal Problem, and Mr. Roy J. Lanphear, Chemist-in-Charge of the Purification Works, will describe the tests being carried out with the Experimental Activated Sludge Plant. Opportunity will then be afforded to inspect the Works. Members may return to Boston either by train or by the Boston & Worcester trolley express. Trains leave Worcester at 4.58, 5.05 and 6.17; trolley express leaves Worcester City Hall on the hour and half hour. Fare by train, \$1.12; fare by trolley, \$0.77.

This excursion will afford an opportunity for us to see in operation not only the older methods of Chemical Precipitation and Sand Filtration, but also the latest development in the art of sewage treatment, known as the Activated Sludge Process. By this process the strong, highly-colored sewage of the city is rendered clear and sparkling. No member who desires to keep in touch with the progress of Sanitary Engineering can afford to miss this opportunity. Send in your reply card promptly and let us show our appreciation of the generous invitation of the Worcester Officials by a large attendance.

ALMON L. FALES, *Chairman.*

HENRY A. VARNEY, *Clerk.*

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### MINUTES OF MEETING.

Boston, April 17, 1918. — A regular meeting of the Boston Society of Civil Engineers was held this evening at Chipman Hall, Tremont Temple, and was called to order by the President, Charles M. Spofford, at 8 o'clock.

There were 75 members and visitors present.

The records of the special meeting of February 27 and the annual meeting of March 20, 1918, were read and approved.

The Secretary reported for the Board of Government the election of the following to membership in the grades named:

Members — Messrs. Leroy G. Brackett, Max Silverman and Earl Stafford.

Juniors — Messrs. Benjamin H. Kerstein and Harry A. Wansker.

Associate — Mr. Rufus R. Moore.

The Secretary announced that, under authority of a vote passed at the annual meeting, the Board of Government had appointed the following committees:

On the Library: S. Everett Tinkham, Frederic I. Winslow and Henry F. Bryant.

On Publication: Charles W. Sherman, John L. Howard and Edwin H. Rogers.

On Papers and Program: Charles M. Spofford, chairman *ex officio*; Harrison W. Hayward, Angus B. MacMillan, Harry E. Sawtell, Frank C. Shepherd, S. Everett Tinkham and Robert Spurr Weston.

On Social Activities: David A. Ambrose, William W. Bigelow, John B. Babcock, 3d, Charles R. Berry, Royall D. Bradbury, Samuel P. Waldron and Luis G. Morphy.

On Membership: Harry F. Sawtelle, Rufus M. Whittet and Henry C. Robbins.

The Secretary presented a memoir of Charles Webster Gay, prepared by a committee consisting of William L. Vennard and Frank B. Rowell, and by vote it was accepted and ordered printed in the JOURNAL.

The following vote passed at the annual meeting of the Society was again passed by a unanimous vote, as required by the By-Laws:

Voted, that the dues for the year 1918-19 be abated to all members in the military or naval service of the United States or its allies; and that a sum not exceeding one thousand dollars be appropriated from the income of the Permanent Fund to reimburse the Current Fund of the Society for the resulting loss.

The President then introduced Commander H. R. Stanford, Civil Engineer, U. S. N., who gave an illustrated talk on the construction of the Pearl Harbor Dry Dock at Hawaii. A short discussion followed the talk, in which Mr. Hodgdon, Mr. FitzGerald and Commander Stanford took part.

After passing a vote of thanks to Commander Stanford for his courtesy in coming before the Society and giving so interesting and instructive a description of this important work, at 9.30 o'clock the meeting was adjourned.

S. E. TINKHAM, *Secretary*.

## APPLICATIONS FOR MEMBERSHIP.

[May 4, 1918.]

THE By-Laws provide that the Board of Government shall consider applications for membership with reference to the eligibility of each candidate for admission and shall determine the proper grade of membership to which he is entitled.

The Board must depend largely upon the members of the Society for the information which will enable it to arrive at a just conclusion. Every member is therefore urged to communicate promptly any facts in relation to the personal character or professional reputation and experience of the candidates which will assist the Board in its consideration. Communications relating to applicants are considered by the Board as strictly confidential.

The fact that applicants give the names of certain members as reference does not necessarily mean that such members endorse the candidate.

The Board of Government will not consider applications until the expiration of twenty (20) days from the date given.

ARONSON, MARK, Boston, Mass. (Age 23, b. Boston, Mass.) Graduate of Mechanic Arts High School, Boston, 1912; graduate of Mass. Inst. of Technology, 1916, civil engineering course, degree of S.B. Is with Dept. of Mechanical Design, U. S. Navy Yard, Boston. Refers to C. B. Breed, H. J. Hughes, C. M. Spofford and H. A. Wansker.

FEAR, HOLBERT WHITE, Cambridge, Mass. (Age 27, b. Gloversville, N. Y.) Graduate of Cornell University, 1913, degree of C.E. For one year immediately following graduation, chainman, rodman and transitman on Barge Canal construction, with Dept. of New York State Engineer and Surveyor; from July, 1914, to date, with U. S. Geological Survey, Water Resources Branch, serving until August, 1917, as junior engr., in which capacity he was employed at Albany, N. Y., on investigation of surface waters of New York and New England, collecting base data, making current meter discharge measurements, etc.; at Washington, D. C., on preparation of water-supply papers; at Boston in charge of office computations of discharge of New England streams; and at Denver, Colo., on similar work; in August, 1917, was promoted to assistant engr., and in November, 1917, returned from Denver to Boston office, where he is now in charge of entire office during absence of district engr. Refers to H. S. Boardman, R. A. Hale, C. H. Pierce, A. T. Safford, W. F. Uhl and D. M. Wood.



HANNA, JOHN BAXTER, Pawtucket, R. I. (Age 27, b. Pawtucket, R. I.) Graduate of Pawtucket High School. From September, 1909, to date, with City Engr.'s Dept., Pawtucket; has served as transitman, levelman, computer, draftsman and assistant engr. on sewer and highway construction. Elected a Junior January 27, 1915, and now desires to be transferred to grade of Member. Refers to G. A. Carpenter, E. S. Patton and F. A. Sweet.

HOYT, LAURENCE BRACKETT, Melrose, Mass. (Age 26, b. Greenland, N. H.) Graduate of Mass. Inst. of Technology, 1913, civil engineering course, degree of S.B. During summer of 1911, rodman with Boston Elevated Ry. Co.; during summer of 1912, rodman with Power Construction Co., Hoosac Tunnel, Mass., and later rodman and instrumentman with Directors of Port of Boston; in 1913-14 assistant in civil engineering, Mass. Inst. of Technology, serving as instructor during summer of 1913 at surveying camp, E. Machias, Me.; while assistant at Mass. Inst. of Technology, did private work on computation and design in connection with bridge apportionment costs; from June, 1914, to date, resident engr. with Mass. Highway Comm. Elected a Junior November 19, 1913, and now desires to be transferred to grade of Member. Refers to C. F. Allen, C. B. Breed, R. W. Coburn, G. L. Hosmer, J. W. Howard and C. M. Spofford.

SNOW, BENJAMIN HARRISON, Everett, Mass. (Age 25, b. Everett, Mass.) Graduate in surveying and structural engineering courses, Northeastern College (Boston Y. M. C. A.) School of Engineering, 1917. From August, 1913, to April, 1914, transitman and inspector with Sterrett & Beners, at Boston Fish Pier; from May to September, 1914, transitman with Whitman & Howard, Boston; from October, 1914, to May, 1916, iron and steel draftsman with Babcock-Davis Corp'n, Cambridge, Mass.; from May, 1916, to date, structural designer with Industrial Service & Equipment Co., Boston. Elected a Junior September 26, 1916, and now desires to be transferred to grade of Member. Refers to B. S. Brown, E. W. Colby, C. S. Ell, H. A. Gray and Channing Howard.

WOODBURY, STANLEY WARD, Haverhill, Mass. (Age 27, b. Haverhill, Mass.) Graduate of Haverhill High School; has completed course in concrete construction at Boston Y. M. C. A. Evening School; has completed half of I. C. S. course in civil engineering. Has had eight years' experience, including four years on construction of highways and bridges, two years on surveying and about two years on drafting and estimating, all with Essex County Engineering Dept., with which Dept. he is still employed. Elected a Junior April 15, 1914, and now desires to be transferred to grade of Member. Refers to B. S. Brown, R. R. Evans, L. C. Lawton and A. D. Marble.

## ROLL OF HONOR.\*

- ATWOOD, JOSHUA. Captain, Infantry, National Army, Headquarters Northeastern Dept., Boston, Mass.
- BABBITT, JOHN H. 1st Lieutenant, C. A. C., U. S. A., commanding 31st Co., Coast Defenses of Narragansett Bay, Fort Adams, R. I.
- BALCH, WILLIAM H. Captain, E. O. R. C., Am. Ex. Force, France.
- BEARD, CORNELIUS. 1st Lieutenant, Company A, 101st Engrs., Am. Ex. Force, France.
- BREATH, ALEXANDER.
- BROWN, H. WHITTEMORE. 2d Lieutenant, E. O. R. C., 301st Engrs., Camp Devens, Mass.
- BROWN, WILLIAM AUGUSTINE. Machinist's Mate, 1st Class, U. S. N. R. F., Navy Yard, Boston, Mass.
- † BRYANT, CHAUNCEY D. 1st-class Private, 101st Engrs., Am. Ex. Force.
- BUNKER, PAGE S. Major, Ordnance, Dept. U. S. N. A., Augusta Arsenal, Augusta, Ga.
- BURLEIGH, WILLARD G. Corporal, Company E, 25th Engrs., Camp Devens, Mass.
- BUSSEY, BYRON C. 2d Lieutenant, E. O. R. C., Officers' Training Camp, Washington, D. C.
- CLAPP, WILFRED A. Q. M. C.
- CLARKSON, EDWARD H., Jr. Sanitary Engineer, American Field Ambulance.
- COBURN, WILLIAM H. 1st Lieutenant, Field Supply Section, Gas Defense Service, New Interior Bldg., Washington, D. C.
- COFFIN, S. P. 1st Lieutenant, Railway Transportation Corps, National Army.
- CRAIGUE, JOSEPH S. Captain, Engrs., U. S. R., Gas Service, Am. Ex. Force.
- CROSS, RALPH U. 1st-class Sergeant, Q. M. C., U. S. A., Headquarters Northeastern Dept., Boston, Mass.
- CURTIS, GREELY S. Lieutenant (j. g.), Naval Militia, Mass.
- DASHFER, FREDERICK C. With British Army.
- DAVIS, HAROLD F. Supply Sergeant, 6th Reg't, Company A, Mass. Infantry, Am. Ex. Force, France.
- DELANO, RAY O. Sergeant, Company B, 301st Engrs., Camp Devens, Mass.
- DEMERRITT, ROBERT E. 2d Lieutenant, C. A. C., U. S. A., Fort Monroe, Va.
- DEMING, GUY S. Captain, Construction Co. No. 12, Aviation Section, Signal Corps, U. S. A., Aviation Mobilization Depot, Camp Levier, Greenville, S. C.
- DRUMMOND, WILLIAM W. Captain, Engrs., U. S. R., Camp Lee, Va.
- DURHAM, HENRY W. Captain, Engrs., R. C., 20th Engrs., Camp American Univ., Washington, D. C.

\* This list is made up from replies to a circular sent out to members of the Society, and from various other sources. That future lists may be more accurate and complete, members are requested to call the attention of the Secretary to any inaccuracies or omissions.

† Died in France.



# PROCEEDINGS.

7\*

- EDDY, HARRISON P., Jr. Assistant Naval Constructor, U. S. N. R. F., U. S. Navy Yard, Norfolk, Va.
- ELKINS, CLAYTON R. Lieutenant, Public Works Dept., Navy Yard, Norfolk, Va.
- ELLSWORTH, SAMUEL M. Company I, 3d Officers' Training Camp, Camp Upton, Long Island, N. Y.
- ENEBUSKE, CARL C. 55th C. A. C.
- FERNALD, GORDON H. 1st Lieutenant, E. O. R. C., 304th Engrs., Accotink, Va.
- FOOTE, FRANCIS C. Lieutenant, 303d Engrs., E. O. R. C.
- FRENCH, HEYWOOD S. Major, Q. M. C., National Army, 2521 University Place, Washington, D. C.
- GERRISH, HERBERT T. 1st Lieutenant, Engr. R. C., E. R. O. T. C., Camp Lee, Va.
- GIBLIN, JOHN F. A. 1st Lieutenant, 101st Engrs., Am. Ex. Force, France.
- GOW, CHARLES R. Major, Q. M. C., National Army.
- GUNBY, FRANK M. Lieutenant-Colonel, Cantonment Div., Q. M. C., U. S. R., 1156 15th Street, Washington, D. C.
- GUPPY, BENJAMIN W. Lieutenant-Colonel, 14th Engrs., Am. Ex. Force, France.
- HALE, RICHARD K. Lieutenant-Colonel, 101st Field Artillery, Am. Ex. Force, France.
- †HANF, FRANK S. 2d Lieutenant, Engrs., U. S. R., 2d Battalion, 2d U. S. Engrs., Am. Ex. Force, France.
- HANNAH, THOMAS E. 1st Lieutenant, C. A. C., Fort Monroe, Va.
- HARTY, JOHN J., Jr. Captain, Ordnance Dept., U. S. R., Springfield Armory, Springfield, Mass.
- HASTIE, FRANK B. 2d Lieut., Engr. Corps, U. S. A.
- HOBSON, GEORGE F. Captain 305th Engrs., Camp Lee, Petersburg, Va.
- HUBBARD, CARL P. Sergeant, Company D, 11th Engrs. (Ry.), Am. Ex. Force, France.
- JACKSON, DUGALD C. Major, Engrs., U. S. R., France.
- KENDALL, THEODORE R. 1st Lieutenant, Sanitary Corps, National Army, care Division Surgeon, Camp Lee, Petersburg, Va.
- KIMBALL, HERBERT S. Captain, Ordnance Dept., Nitrate Div., 202 The Argyle, 3220 17th St. N. W., Washington, D. C.
- LEONARD, JOSEPH F. A. 2d Lieutenant, Engrs., U. S. R., Officer in Charge, Engr. Sub-Depot; Commanding Engr., Depot Detachment 421, Camp Wadsworth, Spartanburg, S. C.
- LOHMEYER, WILLIAM, Jr. 2d Lieutenant, 4th Engrs., U. S. A., Camp Greene, N. C.
- LUTHER, HOWARD B. Lieutenant (j. g.), U. S. N. R. F., 1707 H St. N. W., Washington, D. C.
- MATTSON, WILLIAM R. 1st Lieutenant, Company E, 101st Engrs., Am. Ex. Force, France.

- MONAGHAN, JAMES F. Captain, Ord. R. C., U. S. A., 1330 F St. N. W., Washington, D. C.
- MOORE, LEWIS E. Captain, E. O. R. C., Am. Ex. Force, France.
- NASH, PHILIP C. 1st Lieutenant, E. O. R. C., U. S. A., Washington Barracks, Washington, C. D.
- NOLAN, CONRAD. Corporal, Battery D, 301st Field Artillery, Camp Devens, Mass.
- OBER, ARTHUR J. Major, E. O. R. C.
- OSBORN, JOHN F. Captain, Company B, 101st Engrs., Am. Ex. Force, France.
- PIERCE, CHARLES H. 1st Lieutenant, Engrs., U. S. R., 7th Company, Engr. Reserve Officers' Training Camp, Camp Lee, Va.
- RAND, ROBERT. Lieutenant (j. g.), U. S. N. R. F., Communication Officer, U. S. Naval Headquarters, 4 Place D'Iéna, Paris, France.
- REED, LESLIE P. 2d Lieutenant, U. S. Signal Reserve Corps, Engr. Section, Room 356, Union Station, Washington, D. C.
- RICHARDSON, EDWARD B. Captain, Battery A, 101st Field Artillery, Am. Ex. Force, France.
- RICHMOND, CARL G. 1st Lieutenant, 602d Engrs., Camp A. A. Humphreys, Va.
- SAVILLE, THORNDIKE. 1st Lieutenant, Signal Corps, U. S. A., Construction of Water Supply and Sewerage Systems, Supply Div., Langley Field, Hampton, Va.
- SAWYER, GEORGE S. Sergeant, Company A, 504th Engrs. Battalion, Camp Devens, Mass.
- SHAW, ARTHUR L. Captain, Engr. R. C., 301st Engrs., Camp Devens, Mass.
- SMITH, WILLIAM H. Lieutenant, Asst. C. E., C. E. C., U. S. N.
- SNOW, LESLIE W. 1st Lieutenant, Gun Div., Office of Chief of Ordnance, 1330 F St., Washington, D. C.
- SOUTAR, GEORGE P. Private, 17th Company, 151st Depot Brigade, on detached service studying meteorology at U. S. Weather Bureau, Boston, Mass.
- SPEAR, WALTER E. Major, Q. M. R. C., Camp Upton, Long Island, N. Y.
- STENBERG, THORNTON R. 2d Lieutenant, 301st Infantry, on detached service at School of Military Aeronautics, University of Texas, Austin, Tex.
- STROUT, HENRY E., Jr. Captain, C. E., U. S. A., 319th Engrs., Camp Fremont, Cal.
- THOMPSON, SANFORD E. Major, Progress Section, Office of Chief of Ordnance, Washington, D. C.
- TOSI, JOSEPH A. Private, Company 2, 3d Officers' Training Camp, Camp Devens, Mass.
- TUCKER, HERMAN F. Ensign, U. S. N. R. F., Seattle, Wash.
- WADE, CLIFFORD L. 1st Lieutenant, E. O. R. C., Camp Humphreys, Va.
- WADSWORTH, GEORGE R. Major, Aviation Section Signal Corps, U. S. A., Chief Engr., Naval Aircraft Factory, Navy Yard, Philadelphia, Pa.



- WALKER, ELTON D. Captain, Co. A, 15th U. S. Engrs., Am. Ex. Force, via New York, N. Y.
- WARING, CHARLES T. Major, Supply Div., Signal Corps, Fort Wayne, Mich.
- WEBB, DEWITT C. Lieutenant-Commander, Public Works Office, U. S. Navy Yard, Philadelphia, Pa.
- WELLS, EDWARD P. Cadet, U. S. A. School of Military Aëronautics, Ithaca, N. Y.
- WENTWORTH, JOHN P. Captain, Sanitary Corps, National Army, Quarters No. 9, M. O. T. C., Fort Riley, Kans.
- WESTON, ARTHUR D. Lieutenant, 26th Engrs., Am. Ex. Force, via New York, N. Y.
- WHITMAN, RALPH, Lieutenant-Commander, U. S. Navy, care U. S. Military Gov't, San Domingo, R. D., via Postmaster, N. Y.
- WHITNEY, ORVILLE J. Major, 2d Anti-Aircraft Machine Gun Battalion, Camp Wadsworth, Spartanburg, S. C.
- WHITNEY, RALPH E. 1st Lieutenant, Sanitary Corps, National Army, Surgeon General's Office, Washington, D. C.
- WIGGIN, THOMAS H. Captain, E. O. R. C., Am. Ex. Force, France.
- WOOD, FREDERIC J. Major, Engrs., U. S. R., Curtis Bay Ordnance Depot, South Baltimore, Md.
- WOOD, LEONARD P. Captain, E. O. R. C., Am. Ex. Force, France.
- WORCESTER, ROBERT J. H. 1st Lieutenant, Inf. R. C., Company 12, 3d Battalion, Depot Brigade, Camp Devens, Mass.

## LIST OF MEMBERS.

### ADDITIONS.

WANSKER, HARRY A.....Head House, City Point, South Boston, Mass.

### CHANGES OF ADDRESS.

ALLEN, JOHN E. .... West Branch, Y. M. C. A., Philadelphia, Pa.

BARNES, T. HOWARD. .... 17 Battery Place, New York, N. Y.

BARNES, WILLIAM T. .... 773 Broadway, South Boston, Mass.

BIGELOW, WILLIAM W.,  
With Fay, Spofford & Thorndike, 308 Boylston St., Boston, Mass.

BURRILL, NATHAN C. .... care Quartermasters' Terminal, Norfolk, Va.

CANNON, MADISON M. .... care Public Works Office, Portsmouth, Va.

DOLLIVER, HENRY F. .... 3 Pine St., Belmont, Mass.

EISNOR, JOHN J. .... 59 Thorndike St., Arlington, Mass.

FIELDING, WILLIAM J. .... Balboa, Canal Zone

HARTWELL, DAVID A. .... 24 Allston Place, Fitchburg, Mass.

HOLLAND, NEAL J. .... 307 City Hall Annex, Boston, Mass.

HOLWAY, WILLIAM R. .... Supt. of Filtration, Tulsa, Okla.

HORNE, HAROLD W. .... Englewood, Montgomery County, Ohio

MOODY, HERBERT A. .... Turners Falls Co., Turners Falls, Mass.

|                      |                                                                                               |
|----------------------|-----------------------------------------------------------------------------------------------|
| MORRILL, FRANK P.    | 34 Greenleaf St., Malden, Mass.                                                               |
| NELSON, WILLIAM      | 4 Dwight Apts., Binghamton, N. Y.                                                             |
| PALMER, WALTER T.    | 3 Calumet St., Wollaston, Mass.                                                               |
| PRATT, C. BARTON     | 975 Chestnut St., Manchester, N. H.                                                           |
| REW, MORSE W.        | Emergency Fleet Corp., Passenger Transportation Div.,<br>1319 F St. N. W., Washington, D. C.  |
| SAVAGE, JOHN DANA    | care T. Stuart & Son Co.,<br>Boston Q. M. Terminal, Summer St. Extension, South Boston, Mass. |
| STEARNS, HERBERT R.  | 101 Nehoiden Rd., Waban, Mass.                                                                |
| TREADWELL, EDWARD D. | 39 Marshall Place, Webster Groves, Mo.                                                        |
| VAN DER PYL, EDWARD  | Donora Wire Works, Donora, Pa.                                                                |

## DEATH.

|                |                |
|----------------|----------------|
| HANF, FRANK S. | April 28, 1918 |
|----------------|----------------|

## LIBRARY NOTES.

## RECENT ADDITIONS TO THE LIBRARY.

## U. S. Government Reports.

Coal Fields of United States. Marius R. Campbell.

Cotton Production and Distribution, Season of 1916-17.

Retail Distribution of Softwood Lumber in Middle West.

Ovid M. Butler.

Wholesale Distribution of Softwood Lumber in Middle West. Ovid M. Butler.

Effect of Varying Certain Cooking Conditions in Production of Sulphite Pulp from Spruce. S. E. Lunak.

Experimental Convict Road Camp, Fulton County, Ga. H. S. Fairbank and others.

Geology and Ore Deposits of Mackay Region, Idaho. Joseph B. Umpleby.

Incense Cedar. J. Alfred Mitchell.

Magnesite in 1916. Charles G. Yale and Hoyt S. Gale.

Red, White and Blue Series: Conquest and Kultur; German War Practices; German Treatment of Conquered Territory; War, Labor and Peace; German War Code; Why America Fights Germany.

Report of Provost-Marshall General to Secretary of War on First Draft under Selective-Service Act, 1917.

Sand and Gravel in 1916. R. W. Stone.

Sulphur, Pyrite, and Sulphuric Acid in 1916. Philip S. Smith.



### State Reports.

Massachusetts. Annual Report of State Department of Health for 1916.

Massachusetts. Report of Street Railway Investigation Commission on Problems relating to Street Railways of Commonwealth, 1918. Gift of H. S. Knowlton.

### Municipal Reports.

Concord, Mass. Annual Report of Road Commissioners for 1917.

Danvers, Mass. Annual Report of Water Commissioners for 1917.

Haverhill, Mass. Annual Report of Water Commissioners for 1917.

New Bedford, Mass. Annual Report of Water Board for 1917.

Newton, Mass. Annual Report of City Engineer for 1917.

North Adams, Mass. Annual Report of City Officers for 1917.

Philadelphia, Pa. Annual Report of Department of City Transit for 1916.

Springfield, Mass. Office Reference Pamphlet, Municipal Water Works, for 1917.

Woburn, Mass. Annual Report of Department of Public Works for 1917.

### Miscellaneous.

Building Trades Employers' Association of Boston: Rules for Estimating.

Canada, Department of Interior: Report of Hydrometric Surveys for 1916.

Portland Cement Association: The Reinforced Concrete Cargo Steamship Faith.

Red Cross Institute for Crippled and Disabled Men: Economic Consequences of Physical Disability, a Case Study of Civilian Cripples in New York City, by John Culbert Faries; Memorandum on Provision for Disabled Soldiers in New Zealand, by Douglas C. McMurtrie.

LIBRARY COMMITTEE.



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**BOSTON SOCIETY OF CIVIL ENGINEERS**  
FOUNDED 1848

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**PAPERS AND DISCUSSIONS**

This Society is not responsible for any statement made or opinion expressed in its publications

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**SOME FEATURES OF NEW YORK CITY'S NEW RAPID  
TRANSIT SYSTEM.**

BY ROBERT RIDGWAY.\*

(Presented March 20, 1918.)

FOR the past ten years, New York City has been engaged in constructing a rapid transit system calculated to increase three-fold the facilities which existed before any part of this new system was placed in operation. The work is being done under the direction of the City of New York through the Public Service Commission for the First District of the State of New York, which commission is charged by law with this duty in addition to its work of regulating public service corporations within the limits of the city of New York. The new system has become known as the "Dual System of Rapid Transit," because under two contracts, called "Contract No. 3" and "Contract No. 4," signed on March 19, 1913, it is provided that the new lines are to be operated by two transit companies. The Interborough Rapid Transit Company, under Contract No. 3, is to operate certain lines in the boroughs of Manhattan, The Bronx, Brooklyn and Queens, the new system being an extension of its present subway and elevated systems. Contract No. 4 was made with the New York Municipal Railway Corporation, formed for the purpose by the Brooklyn Rapid Transit Company, which controls the existing "L" lines in the borough of Brooklyn. The

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\* Engineer of Subway Construction, Public Service Commission for the First District, State of New York.



lines covered by Contract No. 4 are in the boroughs of Manhattan, Brooklyn and Queens, and will be operated for the New York Municipal Railway Corporation by the New York Consolidated Railroad Company. Thus all of the five boroughs of the city are provided for in the new program except the borough of Richmond (Staten Island), but a tentative plan has been made for a tunnel to be constructed some time in the future under the channel known as "The Narrows," connecting this borough with the Fourth Avenue subway in the borough of Brooklyn.

Under Contracts Nos. 3 and 4, while the companies contribute to the cost of construction, the city will own the structures except certain lines known as "Company lines," which are extensions of their existing railroads. The companies provide the equipment, which includes third rail, signal and lighting installations, rolling stock, power, transmission lines, etc. The estimated cost of construction is \$342 000 000, and of equipment \$81 000 000, not including \$105 000 000 spent on account of the existing Interborough Rapid Transit subway. The cost of the "L" systems of that company and of the Brooklyn Rapid Transit Company is not included in these figures. The surface lines are not included in the contracts, though most of them are controlled by the Interborough Rapid Transit and Brooklyn Rapid Transit interests. The following table will be of interest as showing the distribution of estimated cost:

#### INTERBOROUGH RAPID TRANSIT SYSTEM.

| City-Owned Lines (New).                        | City Money.  | Company Money. | Total.        |
|------------------------------------------------|--------------|----------------|---------------|
| Construction.....                              | \$86 000 000 | \$58 000 000   | \$144 000 000 |
| Equipment.....                                 | —            | 44 000 000     | 44 000 000    |
| Total.....                                     | \$86 000 000 | \$102 000 000  | \$188 000 000 |
| Company-Owned Lines (New).                     |              |                |               |
| Construction.....                              | —            | \$29 000 000   | \$29 000 000  |
| Equipment.....                                 | —            | 11 000 000     | 11 000 000    |
| Total.....                                     | —            | \$40 000 000   | \$40 000 000  |
| Total cost of new system (Contract No. 3)..... | \$86 000 000 | \$142 000 000  | \$228 000 000 |

# NEW YORK CITY'S NEW RAPID TRANSIT SYSTEM. 195

## *Cost of Existing City-Owned Subways and " L " Connections, Contracts 1 and 2.*

|                                                                                          |               |               |               |
|------------------------------------------------------------------------------------------|---------------|---------------|---------------|
| Construction.....                                                                        | \$59 000 000  | \$11 000 000  | \$70 000 000  |
| Equipment.....                                                                           | ————          | 35 000 000    | 35 000 000    |
| Total.....                                                                               | \$59 000 000  | \$46 000 000  | \$105 000 000 |
| Total for I. R. T. system exclusive of existing Manhattan " L " lines and connections... |               |               |               |
|                                                                                          | \$145 000 000 | \$188 000 000 | \$333 000 000 |

## NEW YORK MUNICIPAL RAILWAY CORPORATION.

| City-Owned Lines (New).                                                                  | City Money.   | Company Money. | Total.        |
|------------------------------------------------------------------------------------------|---------------|----------------|---------------|
| Construction.....                                                                        | \$134 000 000 | \$14 000 000   | \$148 000 000 |
| Equipment.....                                                                           | ————          | 20 000 000     | 20 000 000    |
| Total.....                                                                               | \$134 000 000 | \$34 000 000   | \$168 000 000 |
| Company-Owned Lines (New).                                                               |               |                |               |
| Construction.....                                                                        | ————          | \$21 000 000   | \$21 000 000  |
| Equipment.....                                                                           | ————          | 6 000 000      | 6 000 000     |
| Total.....                                                                               | ————          | \$27 000 000   | \$27 000 000  |
| Total for N. Y. M. System (Contract 4) exclusive of existing " L " lines of company..... |               |                |               |
|                                                                                          | \$134 000 000 | \$61 000 000   | \$195 000 000 |
| Grand total for Dual System, exclusive of existing company-owned " L " lines.....        |               |                |               |
|                                                                                          | \$279 000 000 | \$249 000 000  | \$528 000 000 |

## TRACK MILEAGE IN DUAL SYSTEM.

### *Interborough Rapid Transit Company.*

Existing subway (City owned) —

- 4-track structure, 7.5 miles, 30.0 running track miles.
- 3-track structure, 1.9 miles, 5.8 running track miles.
- 2-track structure, 9.8 miles, 19.6 running track miles.

Total.....19.2 miles, 55.4 running track miles.

Existing " L " lines (City owned) —

6.2 miles, 17.6 running track miles.

## New subway (City owned) —

4-track structure, 11.7 miles, 47.7 running track miles.  
 3-track structure, 3.9 miles, 11.7 running track miles.  
 2-track structure, 8.8 miles, 18.7 running track miles.

## New "L" (City owned) —

3-track structure, 19.8 miles, 59.7 running track miles.  
 2-track structure, 4.1 miles, 9.2 running track miles.

## New "L" extensions (Company owned)

2-track structure, 11.1 running track miles.

## New 3d Tracks on "L" (constructed

by Company), 15.0 running track miles.

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Total (new lines).....246.1 running track miles.

## Add existing "L" lines

(Manhattan R. R. Co.).....90.7

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Total Interborough Rapid Transit...336.8

## NEW YORK MUNICIPAL RAILWAY CORPORATION.

## New subway (City owned) —

4-track structure, 11.2 miles, 46.5 running track miles.  
 2-track structure, 13.7 miles, 28.0 running track miles.

## New "L" lines (City owned) —

3-track structure, 9.2 miles, 27.6 running track miles.  
 2-track structure, 3.4 miles, 6.9 running track miles.

## New "L" extensions (Company owned)

Including C. I. Terminal and Sea

Beach and Brighton reconstruc-

tion..... 36.9 running track miles.

## New 3d Tracks on "L" (Constructed by

Company) ..... 13.8 running track miles.

Manhattan Bridge (4 tracks).... 5.2 running track miles.

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\* Total (new lines).....164.9 running track miles.

Add existing "L" lines incorpo-

rated in new system.....107.0 running track miles.

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Total N. Y. M. Ry. Corp. ....271.9 running track miles.

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\* This includes only additional trackage in the case of reconstructed existing lines; for example, Sea Beach Line — 5 miles, existing 12 miles and as reconstructed 17 miles.



# NEW YORK CITY'S NEW RAPID TRANSIT SYSTEM. 197

## PERCENTAGE OF WORK DONE ON NEW SYSTEM. (Construction and Equipment.)

|                           | I. R. T.      | N. Y. M.      | Total.        |
|---------------------------|---------------|---------------|---------------|
| Estimated total cost..... | \$228 000 000 | \$195 000 000 | \$423 000 000 |
| Cost of work done.....    | 174 000 000   | 151 000 000   | 325 000 000   |
| Ratio.....                | 76            | 77            | 77            |

## MILEAGE — PERCENTAGE IN OPERATION IN NEW SYSTEM.

|                                                  | I. R. T. | N. Y. M. | Total. |
|--------------------------------------------------|----------|----------|--------|
| Total additional track miles to be provided..... | 246      | 164      | 410    |
| In operation.....                                | 67       | 96       | 163    |
| Ratio.....                                       | 26       | 58       | 40     |

The construction and equipment work called for by these contracts is practically 77 per cent. completed. The unfinished work is principally in the borough of Brooklyn, but also includes the Broadway-Seventh Avenue-60th Street line north of 42d Street, of the 14th Street crosstown line, part of which is in the borough of Manhattan; the four pairs of tunnels under the East River; and some odds and ends of other lines. Work on these unfinished contracts is in progress and is well advanced. The building of the proposed Nassau Street subway in lower Manhattan, connecting two tracks of the Center Street Loop at the station under the Municipal Building with the Whitehall Street-Montague Street East River tunnels, has been deferred for the present. Some of the new lines are now in full or partial operation. Of a total track mileage of 410 miles provided for in the new program, 163 miles are now being operated.

Mr. LeRoy T. Harkness, now chief of rapid transit for the Public Service Commission, took a leading part in the preparation of the Dual Contracts as assistant counsel for the commission, and no one is better informed regarding them than he. The following is quoted from his paper presented to the Municipal Engineers of the City of New York in November, 1913:

"The main points in the arrangement with the Interborough Company (Contract No. 3) were:

"1. The company agreed to equip the lines proposed for operation by it in the report of June 5, 1911, at an estimated expense of \$22 000 000, to

contribute \$58 000 000 toward the construction, and when constructed and equipped, to maintain and operate such new lines for a term of forty-nine years in conjunction with the existing subway systems for a single five-cent fare.

" 2. The leases of the existing subways (Contracts Nos. 1 and 2) were leveled so that the subways constructed under those contracts and the new subways will fall into the City's possession at one and the same time.

" 3. The new lines are subject to recaption at the end of ten years, in accordance with the provisions of the Rapid Transit Act. This recaption may be exercised either directly by the City or through a new contractor. Provision was also made for exchanging part of the new subway lines for part of the old so that in the event of recaption the City may take over a complete east side or a complete west side line.

" 4. The so-called Belmont Tunnel extending under 42d Street and the East River to the borough of Queens was turned in as part of the system at a valuation of \$3 000 000.

" 5. The receipts from existing and new subway lines are to be pooled, and from the gross receipts of both lines there is to be deducted and paid in the order named, deficits to be cumulative with compound interest:

" (a) Operating expenses; provision for depreciation, renewals and obsolescence; taxes, insurance and rentals payable to the City under existing subway contracts.

" (b) A sum to be retained by the company amounting to \$6 335 000 per annum, representing the average annual income received by it from the operation of the existing subway lines and equipment for the two fiscal years ending June 30, 1911.

" (c) A sum to be retained by the company equal to six per cent. per annum upon the new investment of the Interborough Company in the new lines, estimated at \$80 000 000, or \$58 000 000 for new construction and \$22 000 000 for new equipment.

" (d) To be paid to the City the interest and sinking fund upon the bonds issued by the City for the construction of new lines, and in addition such further sum as will bring the payments to be made to the City up to an amount equal to 8.76 per cent. upon its expenditures.

" (e) Any amount remaining to be divided equally between the City and the company, share and share alike.

" 6. Future extensions required by the City may be added to the system and will be equipped and operated by the company as part of the entire system under a separate accounting system.

" 7. The company at its own expense is to third track and extend the elevated lines leased by it from the Manhattan Railway Company.

" The main points in the arrangement with the Brooklyn Company (Contract No. 4), the contract being entered into with New York Municipal Railway Corporation, a company specially formed for the purpose, were:

" 1. The company agreed to equip the lines proposed for operation by it in the report of June 5, 1911, to contribute \$13 500 000 toward the con-

struction thereof, and when constructed and equipped, to maintain and operate such new lines for a term of forty-nine years in conjunction with the existing elevated railroad system of the New York Consolidated Railroad Company for a single 5-cent fare.

" 2. The company to expend approximately \$26 000 000 in third-tracking and extending its existing lines.

" 3. The new city lines and also the third tracks and extensions of the existing lines to be subject to recaption at the end of ten years in accordance with the provisions of the Rapid Transit Act. This recaption may be exercised either directly by the City or through a new contractor.

" 4. The receipts from the existing system and the new subway lines to be pooled, and from the gross receipts of both lines there is to be deducted and paid in the order named, deficits to be cumulative:

" (a) Cost of operation which shall include operating expenses, taxes, rentals of leased property used in operation, and provision for depreciation and renewals.

" (b) A sum to be retained by the company amounting to \$3 500 000 per annum, representing the average annual income of the New York Consolidated Railroad Company from the operation of its existing lines.

" (c) A sum to be retained by the company equal to six per centum per annum upon the investment of the company in the new lines.

" (d) To be paid to the City interest and sinking fund charges upon bonds issued by the City.

" (e) Any amount remaining to be divided equally between the City and the company share and share alike.

" 5. Future extensions required by the City may be added to the new city system, and will be equipped and operated by the company as part of the entire system under a separate accounting system."

The fare is five cents on each system, with no free transfers between them. No provision is made in the Dual Contracts for free transfers between the rapid transit and surface lines except at the 86th Street terminus of the Fourth Avenue subway in Brooklyn. There are, however, several points on the existing company-owned lines of the Brooklyn Rapid Transit system where free transfers are given between the "L" and surface lines.

When completed, one may ride a maximum distance of 27 miles and 23 miles on the Interborough Rapid Transit and New York Municipal Railway Corporation systems, respectively, for a single fare of five cents.

The foregoing is intended to give a general summary of the program of rapid transit for the greater city. Doubtless most



of you are familiar with many of the facts set forth, but the speaker has thought best to state them here, since it is found that even in New York, the community most deeply concerned, the significance of the changes in travel to be brought about by the inauguration of the new systems is not yet fully appreciated. It is not the purpose of the speaker to enlarge on the general scheme of operation, to analyze the plan, or to predict the effect of the greater transportation facilities on the community, socially or otherwise. It is thought that a description of some of the features of construction will be more interesting, since, due to his position with the commission, this phase of the work has been more specially under his observation.

Generally speaking, the construction scheme followed has been to build subways under the streets in the borough of Manhattan and in the congested sections of the other boroughs, and elevated structures (Fig. 1) in the less congested sections and in the outlying districts. Parts of three of the company-owned lines of the Brooklyn Rapid Transit Company in South Brooklyn, viz., the Brighton Beach, the Culver and the Sea Beach lines, are in open cuts without cover on the company's rights of way. They have been largely reconstructed and improved in connection with the new development. On Queens Boulevard, a highway of 200 ft. proposed width in the borough of that name, it was decided to substitute an ornamental reinforced concrete viaduct for the ordinary type of steel elevated structure. This problem was treated successfully by the designers and the commission's architect, Mr. Squire J. Vickers. (Fig. 2.) Where stations are located on elevated railroads at crossings of parkways, the steel members of the structures are enclosed in concrete, the faces of which are tooled and decorated with colored tile. (Fig. 3.)

While one usually thinks of a subway as of the standard-type structure seen from station platforms, the local conditions require many variations from this type. The standard four-track subway design (Fig. 4) requires steel bents spaced 5 ft. apart center to center, each bent consisting of two I-beam side columns, an I-beam roof girder, and three interior columns separating the track ways. "Jack" arches of concrete fill the spaces between



FIG. 1. TYPICAL STEEL ELEVATED STRUCTURE IN UNDEVELOPED SECTION.



FIG. 2. QUEENS BOULEVARD ELEVATED LINE TO CORONA IN THE BOROUGH OF QUEENS.



and the roof construction is made deeper on account of the longer span of the girders. The track centers are 12 ft. 6 ins. and 13 ft. 6 ins. apart minimum, in the I. R. T. and N. Y. M. structures, respectively, the one foot difference being due to the fact that the N. Y. M. car is 10 ft. wide, while the I. R. T. car is 9 ft. wide. The vertical distance from base of rail to under side of roof is 13 ft. 2 ins. minimum in both structures. Reinforced concrete in place of the steel bent type has been used for some of the subways, notably for the Center Street loop in Manhattan and the Fourth Avenue Subway in Brooklyn, as well as for the Brooklyn portion of the existing Interborough Rapid Transit subway. The steel bent type, however, is generally preferred by the constructors, not only because it is more convenient to erect, but it makes for safety in construction, as, when the steel frame is erected, the side and vertical loads of the trench can be transferred to it without waiting for all of the concrete to be placed between the bents. In the case of the reinforced concrete structure, the concrete must be allowed sufficient time to harden before it is permitted to take such loads.

When above ground-water level, subdrains are usually placed beneath the track floor. In the original subway, banks of 4-way ducts to carry the power cables were laid up against the outside of each side wall. In the new subway these ducts are laid inside of the subway structure against the side walls, and are enclosed in a concrete bench that will form a walk for passengers in case of an accident in the tunnel. A hand rail is attached to the side wall at a suitable elevation above the bench. About midway between stations an emergency exit to the street is provided, as well as a fan chamber and ample openings leading to gratings in the sidewalks just back of the curb lines. Similar ventilating openings at the approach to each station provide outlets for the air for the purpose of reducing its velocity on the station platforms in front of incoming trains. At low points in the grade, where the drainage will not automatically flow into the sewers, provision is made for sumps and automatic pumps to take care of seepage. In the first subway, the structure was completely waterproofed, generally with an envelope



of asphalt and felt, but in special cases with brick in asphalt mastic. In the new structures the waterproofing has been omitted where the conditions would warrant it, in the interest of economy and because it was believed that the omission would assist in lowering the temperature of the air in the subway by facilitating the radiation of heat through the walls and roof. Such parts of the structure as are below the ground-water level are waterproofed with fabric and coal-tar pitch, or with brick laid in asphalt mastic. It is also the practice to waterproof the roof of the structure at stations with brick in asphalt mastic and between stations with fabric and coal-tar pitch unless the roof is below the level of ground water, in which case brick in mastic is used.

From what has been said it will appear that the development of the subway design during the past fifteen years or more has resulted in a much more complicated structure than the original type, principally due to larger stations with increased facilities and additional provisions for ventilation.

Under Lexington Avenue, in width 75 ft. between building lines, the new subway is built from 43d Street to the Harlem River (about 132d Street) generally as a two-level structure, the local tracks on top following for the most part the grade of the avenue, while the express tracks are below, often in a tunnel, separated from the local tracks above by 10 to 55 ft. of ground. Between 79th and 99th streets the four tracks are in one structure with two local tracks immediately over the two express tracks. For a good part of this distance the structure is built in a rock tunnel, excavated with a cross-section 31 ft. 8 ins. wide by 32 ft. 7 ins. high. At 96th Street an additional width was required in the tunnel, for the platforms of the station for the upper or local tracks. At 99th Street the upper tracks diverge, going north until they clear the roof of the lower tracks, descending thence, relatively to the grade of the lower tracks, until near 103d Street the four tracks are abreast in a rock tunnel. The difficulty of constructing a tunnel of the large and varying cross-section required in the treacherous rock that was encountered in places will be readily appreciated by those experienced in such work. A paper read by Mr. I. V. Werbin, then assistant division en-

gineer for the commission, to the American Society of Civil Engineers, in September, 1916, treats of the difficulties encountered in the construction in an interesting and exhaustive manner. For the half mile north of 103d Street the subway was built by the cut-and-cover method, largely in water-bearing sand below tide level. From 113th Street north to the Harlem River the structure is a particularly complicated one, the tracks flexing in such a way as to come into the two level express station at 125th Street so that the northbound trains, both express and local, are at the upper level, while the southbound trains are at the lower level, thus reducing to a minimum the climb for the homeward or northbound passengers. Just north of the Harlem River the four-track subway divides into two three-track branches, and the flexing of the tracks above described is for the purpose of separating the east branch trains from the west branch trains without a grade crossing. This design required a trench in rock and in water-bearing sand of a depth of over 60 ft. below the street level at the approach to the Harlem River crossing. This long, deep cut, taking practically the whole width of the street, was a particularly impressive sight, and the methods adopted by the contractor for supporting the street loads, including the two electric surface railroad tracks, by means of well-designed timber towers, were very interesting and ingenious and were described in a paper presented to the American Society of Civil Engineers on February 16, 1916, by A. B. Lueder, M. Am. Soc. C. E., and W. J. R. Wilson, the contractor's general superintendent and engineer, respectively.

The Harlem River is crossed by means of a four-track subaqueous tunnel constructed by somewhat the same methods as were used for building the tunnel of the Michigan Central Railroad under the Detroit River. The Harlem River tunnel consists of four steel tubes, 19 ft. internal diameters, the interior walls having flat sides. They were fastened together on their flat sides. At intervals of 15 ft. 7 ins. were transverse steel diaphragms which extended out to the limits of the concrete envelope. The tubes were enclosed in concrete deposited by the tremie method, after the steel shells were sunk in place, forming a structure 76 ft. wide by 24 ft. 6 ins. high. The tubes

are lined with a concrete ring 15 ins. thick except on the flat sides, where it is 12 ins. thick reinforced. The bidders on this contract were given the opportunity of bidding on one, two or three designs, two of the cast-iron shell form, the third of the steel shell form above described. The lowest bid received was for the latter type, and the contract was awarded to the low bidder, Arthur McMullen and Hoff Company. Mr. Hoff, having been associated with the work on the Detroit River tunnel, was exceptionally well qualified to undertake the task of building the Harlem River Tunnel. The contract included not only the subaqueous tunnel 1 080 ft. long, but the north and south approaches as well. The bid price was \$3 889 775.05, of which \$1 620 000 was for the 1 080 lin. ft. of subaqueous tunnel, i. e., at the rate of \$1 500 per linear foot of four-track tunnel complete and ready for track. The width of the channel of the Harlem River from bulkhead to bulkhead measured on the center line of the structure was 600 ft. Therefore the subaqueous tunnel extended a considerable distance inland from the bulkheads, which were necessarily removed during construction and restored afterwards. The Harlem River is a tidal stream, and in order to comply with the requirements of the War Department permit, the top of the structure was placed at a minimum depth of 25.33 ft. below m.h.w., and the bottom was, therefore, 24.5 ft. lower, the greatest depth being about 57 feet below m.h.w. As the original river bed was about 7 ft. above the grade of the top of the tunnel, a considerable amount of dredging was required, mostly in mud and sand, but partly in rock. Approximately 275 000 cu. yds., barge measurement, were dredged for the purpose.

The steel shells were built in five sections in a yard on the Bronx side of the Harlem River, about a mile northwest of the site of the tunnel, somewhat as a steel ship is built. One of the sections was 200 ft. in length; each of the other four was 220 ft. in length. Each section included four tubes with connecting diaphragms. To the latter and to intermediate struts were attached the 4 in. x 12 in. horizontal lagging which acted as a concrete form. The cross-section, as before stated, was 76 ft. in width inside of the 4 in. lagging by 24 ft. 6 ins. high from bottom

to top of diaphragms. Bulkheads were placed in each tube near the ends, carried in every case above the flotation line. As each section was ready for launching, nine canal boats were floated at low tide under it, the rise of the tide lifting the structure off the stringers on which it was built. Tugs pulled the section out into the channel. The canal boats were scuttled and pulled from under, leaving the "sea-going tunnel" riding on the stream. (Fig. 5.) It was towed by tugs to the site of



FIG. 5. TOWING A SECTION OF THE FOUR-TRACK HARLEM RIVER TUNNEL.

the tunnel, a time being selected so that the tide was running slightly against it, this providing better steerage. It was necessary to pass through three drawbridges on the way, — rather a delicate operation. Arrived at the site, the tubes were flooded and sunk into place. (Fig. 6.) Four steel buoyancy cylinders 10 ft. 6 ins. diameter and 68 ft. 3 ins. long, provided with the necessary valves and fittings, were attached transversely to the top of the structure, two cylinders near each end, and assisted in controlling the sinking. Each 220-ft. section weighed when afloat



with its equipment about 750 tons. Masts supporting line and grade targets attached to each end of the section afforded means of accurately adjusting the structure to its vertical and horizontal positions. After this was accomplished, the space below the bottom of the diaphragms caused by overdredging was filled with lean concrete by the tremie method. Then each pocket formed by the diaphragms and the side lagging was filled in one operation, by the same method, with 1 : 3 : 6 concrete. When



FIG. 6. SINKING A SECTION OF THE FOUR-TRACK HARLEM RIVER TUNNEL.

four of the five sections had thus been placed and enveloped with concrete, the tubes were pumped out between heavy bulkheads placed in the ends, and the interior ring of 1 : 2 : 4 concrete reinforced on the flat vertical sides was placed under normal air pressure. Subsequently the fifth section was completed in a similar manner. Connections to the land sections were afterwards made by means of cofferdams. The leakage into this subaqueous tunnel is practically negligible, and the speaker understands that it is less than that of any other transportation

tunnel now in use under New York waters. An evening could be devoted to a description of this tunnel, and for those interested in it the speaker would refer to a paper ably prepared by Mr. Howard B. Gates, assistant engineer in charge of the work, published in the 1915 Proceedings of the Municipal Engineers of New York City. The speaker cannot speak too highly of the manner in which the contractor carried out this large con-



FIG. 7. LEXINGTON AVENUE LINE WHERE IT PASSES THROUGH FRANZ SIGEL PARK IN THE BOROUGH OF THE BRONX.

tract, and particular mention should be made of the work of Mr. Olaf Hoff and of the general superintendent, Mr. N. R. Melvin, a natural-born engineer, possessed of great ability and foresight. The accurate fitting together of all parts of this complicated work, its excellent workmanship and the entire absence of serious accidents during construction is due in large part to these two men.

North of the Harlem River the subway branches into two three-track lines as before stated, which come out of the ground

on to elevated structures beyond the more thickly settled districts. The west side, or Jerome Avenue branch, passes under Franz Sigel Park in a reinforced concrete structure before emerging from the ground. (Fig. 7.)

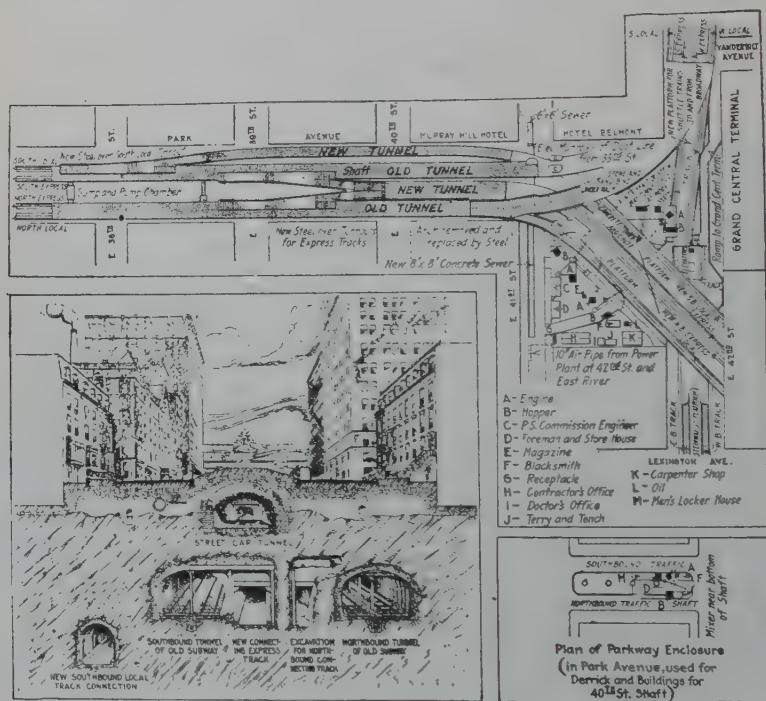


FIG. 8. CONDITIONS AT CORNER OF LEXINGTON AVENUE AND PARK AVENUE NEAR THE GRAND CENTRAL TERMINAL.

One of the most complicated and difficult problems presented to the designers and contractors of the Dual System was the connection between the new Lexington Avenue subway and the existing subway under Park Avenue in the vicinity of the Grand Central Terminal at 42d Street. (Fig. 8.) Both of these subways have four tracks, and those of the existing subway at the points of connection are in two double-track, concrete-lined rock tunnels. The operation of the existing subway, involving the

handling of over a million passengers daily and the passing of a train on one of the four tracks during rush hours about every thirty seconds, could not be interrupted. The work had to be carried on with due regard to this operation and with safety as the first consideration. For these reasons and because of the limited space inside of the operating subway, the work of demolition and construction was necessarily done from the outside of the old structure. It was provided that no tracks should cross at grade. Briefly, the design provided for taking the two express tracks out of the present tunnels at a point near 39th Street and bringing them into a new rock tunnel located between the existing tunnels, the new tunnel descending on a 2.5 per cent. grade until it is low enough to pass under the present northbound tunnel, when it curves to the east and emerges into the open cut on the site of the Old Grand Union Hotel between 41st and 42d streets. Similarly, the southbound local tracks are taken out of the old structure near 38th Street into a single-track rock tunnel extending north under the west sidewalk of Park Avenue, and descends until it can pass under both of the present tunnels, when it curves east also into the Grand Union site. The new northbound local track descends from a point between 40th and 41st streets, keeping its present alignment until it, too, curves into the same property. As an indication of the difficulties of the mining operations involved, a cross-section of Park Avenue near 40th Street now shows four double-track tunnels and one single-track tunnel, one double-track tunnel for the surface car operation, two for the present Interborough Rapid Transit operation, one for the new express operation, and the single-track tunnel for the new southbound local operation.

Through the Grand Union property, across 42d Street and through the New York Central property to 43d Street and Lexington Avenue, all four tracks are parallel and at the same level. Here is the site of the new Grand Central Subway Station, containing two island platforms with mezzanines and the necessary entrance and exits. This is destined to become a great transfer point, facilities being provided for exchanges between the Lexington Avenue subway, the shuttle service to Times Square,



and the Queensborough Tunnel to the borough of Queens. Facilities will also be provided for entrances to the Grand Central Station of the New York Central Railroad Company, to the new Hotel Commodore, and to the new building to be erected on the site of the former Grand Union Hotel.

Across the Grand Union property the structure is designed to carry a 25-story building, and it is intended to sell the property, which was acquired in fee by the City, subject to a permanent easement for the maintenance and operation of the subway through it. Because of the heavy column loads to be carried, great care was taken to secure proper foundations. Sometimes the contractor's representatives thought the engineers were rather too particular and made them go to an unnecessary depth for the purpose, and some good-natured bantering took place about it. The work was well and faithfully done, and there was excellent coöperation between the engineers and the contractor to secure good results.

For the structure crossing the New York Central property between 42d and 43d streets, an easement was obtained from the railroad company, under the terms of which the company constructed the subway there, and the right was given the City to maintain and operate it. The new Hotel Commodore is now being erected over and about this subway structure, and, as before stated, there will be connections between the station platforms and this hotel, as well as with the Grand Central Station of the New York Central Railroad.

The pair of single-track tunnels now named the "Queensborough Tunnel," formerly known as the "Belmont," and earlier as the "Steinway Tunnel," extended east from Park Avenue under 42d Street and the East River to Long Island City in the borough of Queens. The tunnels, which were built between 1905 and 1907, have in part been reconstructed in connection with the Dual System program. The island platform east of Lexington Avenue has been extended over five hundred feet west, ending at a shaft about 63 ft. square east of Park Avenue, in which three passenger elevators operate between this station platform about 70 ft. below the street surface, and the mezzanine about 19 ft. below the street surface. The ex-

tension of the platform involved the lowering of the two existing tunnels a maximum of about 7 ft. and the removal of the core of rock between them for a length of about 535 ft., all of which extremely difficult work was accomplished without trouble, due to the ingenious methods and the care employed. This work was done before operation on that part of the Queensborough Tunnel was begun. Other features of this tunnel reconstruction were the excavation of the core of rock between the two tunnels for a length of about 240 ft. near the Manhattan shore of the East River, to provide for a crossover between the tracks; the extension of the two tunnels west to Vanderbilt Avenue from which point it is planned to extend them later with a view to carrying the operation to Times Square; and the construction of a tunnel ramp connection between the station of the tunnel and the new Grand Central subway station overhead. The difference in elevation between the two platforms is about 40 ft.

As the present routing of subway trains under 42d Street will be discontinued when the new Lexington Avenue and Seventh Avenue lines are placed in operation, provision is made for a shuttle service between the Grand Central and Times Square stations. In connection with this, two of the four tracks of the existing subway are to be extended east from the present Grand Central station to a point convenient for transfer to and from Lexington Avenue trains and Queensborough Tunnel trains. An extended platform is required by this change and is being constructed.

There is not time to describe the many interesting engineering features of the work in this vicinity. They are, however, covered in an excellent paper read to the American Society of Civil Engineers in December, 1917, by Mr. George Perrine, assistant tunnel engineer for the contractor, the Rapid Transit Subway Construction Company, of which Mr. George H. Pegram is the chief engineer. The tunnel engineer in charge for the contractor, Mr. Robert A. Shailer, is well known to the members of this Society, and the general superintendent, Thomas McCormack, deserves more than a word of commendation for the excellent manner in which this difficult work was carried out under his supervision. A false step or a little laxity might

easily have led to an appalling catastrophe. The cost of the work covered by the two contracts of the company in this vicinity will be about \$3 500 000. There is still an opportunity for members of the Society to inspect this work, and the speaker feels that those who do so will feel amply repaid for the effort.

The connection between the present subway and the new Seventh Avenue line at Times Square, completed about two years ago under a contract with the Holbrook, Cabot & Rollins Corporation, also presented many interesting and novel features including the reconstruction of a part of the old subway under operation conditions. Here the depth of cover was so slight that in order to carry on the work of reconstructing the subway roof with a minimum of interference with the extremely heavy street traffic at that point, the decking for the temporary street surface between 43d and 45th streets was raised about 2 ft. above the street grade, the surface car tracks with their heavy underground construction being jacked up correspondingly. Ramps at each end of the stretch and at the intermediate street intersections connected the elevated decking or bridge to the existing pavements. Under the decking the work of cutting out the old roof and side walls and constructing the new was carried on. At the conclusion of the work the permanent street surface was restored approximately at the old grade. When it is considered that the clearance between the cars and the subway roof which was cut out and replaced was a matter of only a few inches, some idea of the difficulties of reconstruction will be appreciated.

The layout of the various new lines required the crossing of existing subways and other railways, exclusive of surface-car lines, at 15 points, 12 immediately underneath and 3 overhead, in addition to connections made to existing subways at grade. In every case but one the existing lines affected were in operation at the time the work was done. In the case of the overhead crossing of the Interborough Rapid Transit subway at Mott Avenue and 149th Street, it was necessary to put out a length of concrete arch lined with brick, which spanned two tracks and two station platforms, substituting a flat girder roof which formed the floor of the new construction overhead. Some

of the undercrossings were entirely in rock, the latter being in contact with the floor of the old construction. Some were partly in rock and partly in earth. One under the New York and Harlam tracks at Park Avenue and 60th Street was in an old rock fill with the soft ground of an old swamp below. Others were entirely in soft ground, ranging from coarse dry sand to saturated fine sand approaching quicksand. In several instances provision for the later subways had been made in the design of the earlier ones so as to make the task of maintenance while drifting under them easier, but generally this was not the case because when the earlier work was done the later subway routes had not been established. Each one of these crossings possessed features of peculiar interest to the constructing engineer, but reference will be made here only to the building of the two-track Canal Street subway under the four-track subways of the Interborough Rapid Transit Company and the New York Municipal Railway Corporation at Lafayette Street and at Center Street, respectively.

The Canal Street subway connects the Fourth Avenue subway in Brooklyn with the new Broadway Line in Manhattan, crossing over the East River on the Manhattan Bridge. The crossings referred to are between the bridge and Broadway. The surface of Canal Street at these crossings is about 13 ft. above m.h.w., and the subgrade of the lower or crosstown line is from 33 ft. to 35 ft. below m.h.w. in water-bearing sand of varying degrees of fineness, some of it being coarse and well graded enough to be used in the concrete. The rock lies at a considerable depth below subgrade. While no accurate figures are available, the contractor estimates that at the time of maximum pumping he took care of a flow of 10 mil. gals. daily, the water coming from various depths in a length of several hundred feet. The design of the Center Street Subway, built about ten years ago, provided a girder floor supported on concrete steel piles as a provision for the future work below it. The Lafayette Street subway made no such provision. When it was built between 1900 and 1904 the crosstown line had not been adopted; consequently it was more difficult to pick up and maintain. It was necessary to lower the ground water very carefully and gradually



in order to prevent a serious loss of material, but this was successfully accomplished. The pumping affected the water level for a large area, and complaints were received from buildings a half mile or so away which maintained pumping plants that the ground water at their pumps had been lowered enough to seriously inconvenience them, these buildings being nearer to the North River in some cases than to the work described. The water was fresh, notwithstanding the fact that pumping was maintained during the construction of this and the adjacent sections to the west for at least four years within three quarters of a mile of both rivers. The contractor, the Underpinning and Foundation Company, devised and successfully used an ingenious method of supporting the sides of the cut by means of concrete walls four feet thick instead of by the use of wood or metal sheeting. These walls acted likewise as lateral supports for the adjacent buildings. Not being gravity walls, however, it was necessary to securely brace them with an interior system of timber sets. The steel roof girders of the subway were in some instances used in connection with this system of bracing, being set 6 in. or more above their proper grade when the excavation had reached that depth and securely wedged against the faces of the protection walls. Afterwards, when the excavation was completed, these girders were loosened and lowered one at a time on their columns and riveted in place, the side thrust then being taken by the permanent steel and concrete structure. Careful consideration was given to the design of this subway before a decision was reached, and on account of the fact that it would be submerged in saturated sand, an opportunity was given contractors to submit alternative bids on a tunnel design that would permit the use of compressed air. The bids received indicated the adopted open-cut design to be a far more economical one than the tunnel design. On account of its great depth in water-bearing sand, this structure, which is completed and in operation, attracts more than usual interest, particularly the problem of waterproofing it. It is waterproofed generally by the use of brick in mastic. In special cases where there are concentrated loads, lead sheets are employed. It was required to connect this waterproofing to that of the existing structures,

and it is not necessary to point out to those who have had experience in such work the difficulty, if not impossibility, of securing an absolutely perfect job. Some annoying leaks developed, particularly during the extremely cold weather of the past winter, where the new and old structures are in contact, due, in measure at least, to the contraction of the masonry and the waterproofing. From the nature of things, these leaks are



FIG. 9. PARK PLACE — BEEKMAN STREET SUBWAY AT THE LOCATION OF THE UNITED STATES POST OFFICE BUILDING.

very difficult to repair, but measures are being taken to correct them that will be effective, it is believed.

The Seventh Avenue Interborough Rapid Transit line is a four-track structure from a connection with the present tracks at Times Square down Seventh Avenue, Varick Street and West Broadway to Park Place, two tracks continuing down Greenwich Street and under Battery Park to a connection with the present South Ferry Loop. The other two tracks turn east under Park Place at a depth great enough to avoid grade cross-

ings at the turn-out, continuing under the two-level subway in Broadway, which forces the subgrade of this line to a depth of more than 60 ft. below the street. The structure then passes under the General Post Office Building (Fig. 9) at its widest part, under the Interborough Rapid Transit subway at Park Row, under Beekman Street in a soft-ground tunnel, down William Street in cut and cover, and under the East River to a connection with the present subway under Fulton Street near the Borough Hall Station. The alignment under the Post Office Building is so arranged that the center line of the structure coincides approximately with one of the lines of building columns, while the two adjacent lines of building columns follow approximately the side lines of the structure. The concrete foundations of the Post Office Building rested on sand, relatively coarse, approximately at elevation 103 ft. (elevation 100 ft. being mean high water), while the roof of the subway is from 6 ft. to 8 ft. below these foundations. The deepest point of the subway excavation is about 25 ft. below mean high water and about 28 ft. below the Post Office Building foundations. The ground-water level when work began was approximately 11 ft. below mean high water, and was slowly and carefully pumped down to subgrade as the excavation progressed, the pumping operations requiring months of time. Drainage ditches were used leading to temporary sumps from which the water was pumped into the sewers. The sequence of the contractor's operations were so arranged that the time so consumed did not delay the completion of the work. In all, 63 column and pier loads had to be carried to greater depths in connection with the subway construction, and are now supported either on the subway structure or on piers carried down to or below subgrade just outside of the walls. The heaviest pier or column load to be taken care of in connection with the underpinning operations was about 1 100 tons. The contractor, F. L. Cranford, Inc., and his engineer, James C. Meem, applied a very ingenious method for underpinning the building. Enough of the sub-basement floor was taken up to uncover the column foundations affected, and a portion of the longitudinal footing was cut off on each side of each of the three lines of columns. Thirty-inch built-up lattice girders

were placed against the column footings into which horizontal holes were drilled and 1½-in. square dowel pins inserted between the diagonals of the lattice girders. On top of these 30-in. girders 15 ins. built-up lattice girders were placed transversely against the column footings and were enclosed in a mass of concrete, thus forming a reinforced concrete girder paralleling the subway structure for the full width of the Post Office Building, about 280 ft. Pits, 5 ft. by 5 ft. in horizontal section, were sunk at intervals under these girders to the level of ground water, and 14-in. sheet steel piles were driven or jacked down to a firm bearing below subgrade and filled with concrete, each pile being tested by hydraulic jacks, which reacted against the girder to a load 50 per cent. in excess of the calculated load it would have to carry. This meant that many of the piles were tested up to a load of 50 tons. When the necessary number of piles had been placed, the pit over them was filled with concrete, and its share of the load of the reinforced concrete girder and the building then was transferred to it. When the design required it, instead of filling the pit with concrete, a set of underpinning columns, so spaced as to permit the subway roof steel to pass between them, was erected in the pit on the pile cap. This method was continued until the entire length of each girder was supported by the concrete piers with their pile foundations, thus transferring the loads of the three lines of building columns and piers to the new underpinning structure. Then, the water level having been lowered in the meantime, the excavation was taken out to subgrade, exposing the steel piles as the work advanced, the subway construction followed up close and the column loads were again transferred, this time to the subway structure except those which had been permanently supported on underpinning piers outside of the structure. Such of the piles as were in the trackways were cut out, and the others were incorporated in the center or side walls of the subway. The slight settlement in the building overhead is not apparent from an inspection of the fine cut exterior granite faces, although cracks of no importance structurally appeared in the interior walls and in the plastering. The work described did not interfere in any way with the use of the building except that part of the sub-basement which



was occupied by the contractor in connection with his construction operations. The plungers for the elevator system of the building were located about 20 ft. away from the side of the subway excavation and were continuously operated without any trouble so far as is known to the speaker.

This same two-track subway passes under William Street for a distance of one-half mile. The width of the excavation is about 29 ft., increasing at the two stations to the full width of the street, 40 ft. The high office buildings give this narrow street a canyon-like appearance. The work was done by the cut-and-cover method, traffic being maintained on the temporary decked surface of the street, which decking was supported by the trench timbering. Spoil was removed through three shafts or hoistways, located at Hanover Square, at Maiden Lane, and on property acquired by the City where the line turns from Beekman Street into William Street. The depth of the excavation ranged from 25 ft. to 31 ft., extending from 3 ft. to 20 ft. below mean high water, the low point being at the south end of the section at the junction with the Old Slip-Clark Street river tubes. The water was slowly lowered by careful and judicious pumping as the work progressed. The material ranged from coarse to fine sand, with some clay. But for the care and foresight of the engineer and the contractor, great trouble would have been experienced in executing this work. The impression had been given some of the owners that it was not a practicable proposition to build a subway in this street without seriously damaging the buildings, but they have been reassured by the results. Every one of the seventy-five or so buildings facing William Street in this stretch required underpinning except a few of the more modern buildings which were supported on caissons extending to rock. The buildings ranged in height from four to twenty stories above the sidewalk, the highest one being the Kuhn, Loeb Building, at the southeast corner of Pine and William streets. This twenty-story building was also the highest one of the many hundred buildings underpinned in connection with subway construction. Its foundations, consisting of a grillage of steel beams enclosed in masonry floated on saturated sand, were approximately 15 ft. below the street level, and it was

necessary to carry them 15 ft. or so deeper and to cut off 5 ft. or more of the old grillages where they extended into the street occupying space required for the subway. Many novel and ingenious methods were used by the contractor in connection with the underpinning, and their success reflects much credit on this firm and its engineers. The contractor is Smith, Hauser & MacIsaac, Inc. It will cost, exclusive of track, about \$2 500 000, of which approximately \$600 000 represents the cost to the City of the underpinning.

The Dual System required the construction of four pairs of tunnels under the East River, excluding the Interborough tunnel now in operation from South Ferry to Joralemon Street, and the Queensborough Tunnel at 42d Street, before mentioned. With the Pennsylvania and Long Island Railroad tunnels, this will make eight pairs or sixteen single tubes available for transportation purposes under this river. The new tubes being constructed are the Interborough tunnel, from Old Slip, Manhattan, to Clark Street, Brooklyn, and the three New York Municipal Railway Corporation tunnels from Whitehall Street, Manhattan, to Montague Street, Brooklyn; from 14th Street, Manhattan, to North Seventh Street, Brooklyn; and from 60th Street, Manhattan, to North Jane Street, Queens. All of these four tunnels are of the usual type of circular, cast-iron lined tubes, shield driven under compressed air in the soft ground and in the rock where the latter structure was weak enough to require it. Where there was sufficient cover of good, sound rock, ordinary tunneling methods in free air were employed. The grades were fixed by the local conditions, and by the conditions of the War Department permits which required a minimum depth to the tops of the tubes at pierhead lines of 45 ft. below mean low water, or approximately 50 ft. below mean high water. The deepest one of these tunnels, in fact the deepest of all the transportation tunnels under New York waters, is the so-called 60th Street Tunnel (Fig. 10), the profile of which presents a number of interesting features. Blackwell's Island at that point divides the East River into two channels, the easterly one being comparatively shallow, while the deepest point of the westerly one extends down to the spring line of the tunnel. The lowest point

of subgrade was fixed about 110 ft. below mean high water. Soon after the contract was let, the contractor placed a blanket of clay of a thickness calculated to provide a cover of approximately 40 ft. over the shields while they are being driven. On the completion of the tunnel, some of this blanket must be removed, as the War Department permit requires 55 ft. of water in the channel at mean low tide. This blanket is held in place



FIG. 10. TUNNELING UNDER THE EAST RIVER FOR THE 60TH STREET TUNNELS.

by two walls of rip-rap, or rock tunnel spoil, extending across the channel, parallel with and about 50 ft. outside of the tunnel construction. The width of this embankment from outside to outside of rip-rap is approximately 120 ft. The current runs very strong at this point, as one would infer from the great depth and narrow width of the channel. Blackwell's Island is a rock of reef or ridge, and there is also rock both on the Manhattan and Queens sides. Shafts were sunk in the rock on the Manhattan side and on Blackwell's Island of a width sufficient to permit the

turning of the four tunnel headings, two in each direction. The Manhattan shaft is about 100 ft. deep, the Blackwell's Island shaft about 130 ft. deep. After the tunnel headings were turned, the permanent concrete lining was placed in the shafts which are to be used as ventilation openings and emergency exits. The contractor, the Patrick McGovern Company, of Boston, attacked the work in a most energetic way, and has made excellent and consistent progress from the start. The plan adopted was to drive the rock tunnels each way under Blackwell's Island and riverward from the Manhattan shaft and from the portal on the Queens side as far as it was safe to go without compressed air; also to extend the rock tunnels in free air landward under 60th Street, Manhattan. All of this work has been done and the tunnels are partly lined with concrete. For the subaqueous portion, two large shields were installed on the Queens side and to date have been driven under the east channel and into the Blackwell's Island workings. The south tunnel under Blackwell's Island was excavated large enough to permit the shields to be shoved through it while the north tunnel was excavated only to normal size and has been lined with concrete. Beyond the limits of this concrete lining cross-connections were excavated between the two tunnels, to permit the rolling of the north shield through into the south tunnel, skidding it through the latter to the westerly cross connection and rolling it back again to the north tube to resume its journey under the west channel. These two shields, therefore, will be used for all of the subaqueous work, and it will not be necessary to install two additional ones on the Manhattan side. To date, the south shield having completed its work under the east channel has been skidded through the rock tunnel already excavated under Blackwell's Island and is now in a position to tackle the deep work under the west channel. It is expected in the course of a few weeks that the maximum air pressure of 45 lbs. or more will be on, and the engineers are looking forward with interest to this phase of the work. Those of the membership who attended the annual meeting of the American Society of Civil Engineers probably visited the Queens end of this tunnel by invitation of Mr. McGovern, and will remember the hospitality of the contractor, who entertained



the party at a luncheon served in a section of the completed subway there. The shields being used were designed by the contractor and his engineer, Mr. A. A. Cohill, in coöperation with Mr. J. R. Worcester, of Boston, and embody some unusual features.

The speaker has attempted to sketch in a general way a few of the many interesting features of the subway construction with which he has been connected during the past six years, but it is not possible to describe them in detail at this time. There are many other features of the work quite as interesting as those which have been mentioned, such as the excavations in deep dry sand in Brooklyn, the passing under and underpinning of the Long Island Station at Flatbush Avenue, and the deep earth tunnel under a portion of Flatbush Avenue at Prospect Park, where the contractor is using a roof shield spanning two tracks, moving it ahead on concrete bench walls previously constructed in timbered drifts. Time could also be spent describing the changes in sewers made necessary on account of subway construction, these changes costing in the aggregate millions of dollars. A paper could also be written on the work of maintaining, restoring and reconstructing the intricate system of underground public utilities on which so much of the business and social life of the greater city depends.

The work described has been done by contractors supervised by the Engineering Department of the Public Service Commission for the First District of the State of New York. The contractors employed a maximum force of probably 18 000 men during the period of greatest activity. Their present force is about 7 000 men, though at least 50 per cent. greater force could be worked to advantage if it could be secured; but war conditions seem to make this impracticable. Prior to 1912, the contracts were let on the lump sum basis. Since then, with very few exceptions, the unit price method has been followed. This necessarily means dozens of schedule items in all of the major contracts, and the work involved in connection with the making of the monthly and final estimates is a severe tax on the field and office staff. It is difficult, however, to simplify this work if the unit form is to be followed. The speaker believes

that in spite of all these and other objections to it, the unit price form of contract is preferable to the lump sum contract for such work as that under discussion here. The maximum force of all grades employed by the Engineering Department of the Commission was 2 127 in December, 1915. This has been largely reduced since, the present force being 1 200 men of all grades. It is hardly necessary to state that the war, directly and indirectly, has drawn very heavily on the force and impaired the efficiency of the department. The commission's service flag has 255 stars, representing men in the military and naval service of our country, most of them from the Engineering Department. Many of these men are on duty in France. Four were officers in the Engineer Regiment which distinguished itself so conspicuously near Cambrai on November 30, last, and one of them was cited by the British commander with other members of the regiment for distinguished gallantry on that occasion.

The commission and its chief engineer, Mr. D. L. Turner, as well as the speaker, extend an invitation to the members of the Society, collectively and individually, to visit the work which is being done in connection with the Rapid Transit System of New York, and it would give the speaker pleasure to arrange for such visits at such times as may be convenient to the members.



## MEMOIR OF DECEASED MEMBER.

CHARLES W. GAY.\*

(Died February 1, 1918.)

CHARLES W. GAY was born in South Dedham, now Norwood, Mass., April 28, 1848, the son of Ebenezer F. and Sarah A. (Webster) Gay.

After completing courses in the Dedham public schools he entered the office of the late Prof. John B. Henck, of the Massachusetts Institute of Technology, and was engaged on laying out large portions of the Back Bay district of Boston, which work was considered at that time to be one of the most accurate surveys that had been made in Boston, and later continued his studies in the office of Col. H. W. Wilson, Boston, where he was engaged in preparing assessors' maps of South Boston.

About this time he was engaged on important street planning in Washington, D. C., laying out new lines under the direction of the national board of public works.

In 1872 he opened an engineering office in Lynn, Mass., where he continued to work at his profession until his death. He prepared plans for and supervised the work of construction of Birch Pond for the Lynn Water Works during 1873-75.

He entered public life in 1884 as a member of the common council, and in 1888 was elected city engineer of Lynn, which office he held eight years, later serving the city as a member of the board of public works seven years. He was of modest disposition but did not hesitate to assert himself in public print, and was ever alert to the possibilities of the future development of Lynn.

He was an expert surveyor, and was considered an authority

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\* Memoir prepared by William L. Vennard and Frank B. Rowell.



on real estate boundaries in Lynn and vicinity; and few men had more to do with street and civic development in the vicinity of Lynn than Mr. Gay. He laid out a large part of Swampscott and Nahant, and in the eighties began the construction of the sewer system of Lynn.

He was of the sterling type of men, with high principles, and a true friend to those who won his friendship. He was married, January 27, 1873, to Rosamond A. McLaughlin, in Andover, who with his sister survive him.

Mr. Gay was a member of the American and Boston Societies of Civil Engineers, was a thirty-second degree Mason, a member of the Mystic Shrine and local clubs.

The loss of his daughter, Florence Webster Gay, in December, 1917, greatly affected him, and doubtless hastened his death, as he had been suffering from heart and kidney trouble.

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## INDEX TO ADVERTISERS.

|                                                                               | PAGE |
|-------------------------------------------------------------------------------|------|
| A. B. SEE ELECTRIC ELEVATORS, 111 Devonshire St., Boston.....                 | XIV  |
| ABERTHAW CONSTRUCTION Co., 27 School St., Boston.....                         | XIII |
| ADAMS, H. S., 108 Ames Building, Boston, Mass.....                            | III  |
| ASPINWALL & LINCOLN, 3 Hamilton Pl., Boston.....                              | III  |
| ASSOCIATED ARCHITECTS PRINTING & SUPPLY Co., 144 Congress St.,<br>Boston..... | XIII |
| BAY STATE DREDGING AND CONTRACTING Co., 62 Condor St., East<br>Boston.....    | IX   |
| BEATTIE, INC., ROY H., 70 Kilby St., Boston.....                              | XII  |
| BISHOP, J. W., & Co., 683 Atlantic Ave., Boston.....                          | X    |
| BLAIR, ISAAC, & Co., INC., 433 Harrison Ave., Boston.....                     | X    |
| BOND, HAROLD L., Co., 383 Atlantic Ave., Boston.....                          | VII  |
| BUSS, EDWARD A., 85 Water St., Boston.....                                    | III  |
| COLEMAN BROS., 1 Marginal St., Chelsea.....                                   | XII  |
| DIXON CRUCIBLE Co., Jersey City, N. J.....                                    | XII  |
| EASTERN BRIDGE AND STRUCTURAL Co., Worcester.....                             | XIV  |
| FAY, SPOFFORD & THORNDIKE, 308 Boylston St., Boston.....                      | III  |
| FORT HILL PRESS, 176 High St., Boston.....                                    | XIV  |
| FULLER, GEORGE W., 170 Broadway, New York.....                                | III  |
| GOW, THE CHARLES R., Co., 166 Devonshire St., Boston.....                     | XI   |
| HALL, JOHN G., & Co., 114 State St., Boston.....                              | XII  |
| HARRINGTON, EPHRAIM, 20 Pemberton Sq., Boston.....                            | III  |
| HERSEY MFG. Co., South Boston.....                                            | XVI  |
| HOLBROOK, CABOT & ROLLINS CORPN., 6 Beacon St., Boston.....                   | VI   |
| HOLZER, U., 25 Bromfield St., Boston.....                                     | IX   |
| HUGHES, EDWARD F., 8 Oliver St., Boston.....                                  | XII  |
| JACKSON, D. C. & WM. B., 248 Boylston St., Boston.....                        | III  |
| JONSBURG, F. F., Co., 733 Old South Building, Boston.....                     | X    |
| LEDGER & PROBST, 56 Franklin St., Boston.....                                 | XII  |
| LEY & Co., INC., FRED T., Springfield, Mass.....                              | XV   |
| MAIN, CHARLES T., 201 Devonshire St., Boston.....                             | II   |
| METCALF & EDDY, 14 Beacon St., Boston.....                                    | III  |
| MORSE, WILLIAM F., 90 West St., New York.....                                 | III  |
| NEW ENGLAND BUREAU OF TESTS, INC., 12 Pearl St., Boston.....                  | IV   |
| NEW ENGLAND FOUNDATION Co., INC., 70 Kilby St., Boston.....                   | XII  |
| NEW ENGLAND SAND & GRAVEL Co., West Peabody, Mass.....                        | VII  |
| OLD CORNER BOOK STORE, 27 Bromfield St., Boston.....                          | XII  |
| PALMER, JOHN E., 1012 Old South Bldg., Boston.....                            | XII  |

|                                                           | PAGE |
|-----------------------------------------------------------|------|
| PENN METAL CO., 201 Devonshire St., Boston.....           | IV   |
| PENNSYLVANIA CEMENT CO., 161 Devonshire St., Boston.....  | X    |
| PERRIN, SEAMANS & CO., 57 Oliver St., Boston.....         | XI   |
| RIDEOUT, CHANDLER & JOYCE, 178 High St., Boston.....      | XII  |
| ROCKPORT GRANITE CO., Rockport, Mass.....                 | V    |
| SIMPSON BROS. CORPN., 166 Devonshire St., Boston.....     | V    |
| S-M-I ENGINEERING COMPANY, 136 Federal St., Boston.....   | IV   |
| SMITH, B. F., & Co., 60 Federal St., Boston.....          | XII  |
| STONE & WEBSTER, 147 Milk St., Boston.....                | VIII |
| THOMPSON, SANFORD E., 136 Federal St., Boston.....        | III  |
| THORPE, LEWIS D., 201 Devonshire St., Boston.....         | III  |
| TUCKER, EDWARD A., Co., 683 Atlantic Ave., Boston.....    | V    |
| WALDO BROTHERS, Boston.....                               | IX   |
| WARREN FOUNDRY AND MACHINE CO., 111 Broadway, New York... | VII  |
| WESTON & SAMPSON, 14 Beacon St., Boston.....              | III  |
| WHITMAN & HOWARD, 220 Devonshire St., Boston.....         | IV   |
| WITHEROW STEEL CO., 185 Devonshire St., Boston, Mass..... | XIII |
| WOOD, R. D., & Co., Philadelphia.....                     | VII  |
| WORCESTER, J. R., & Co., 79 Milk St., Boston.....         | IV   |

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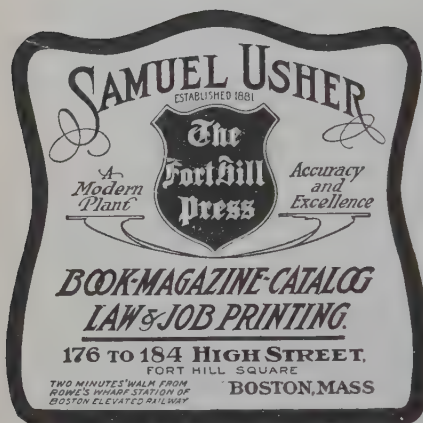
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